Battelle
The Business of Innovation

# Using NASA Satellite Aerosol Optical Depth Data to Create Representative $PM_{2.5}$ Fields for Use in Human Health and Epidemiology Studies in Support of State and National Environmental Public Health Tracking Programs

**Dr. Amy K. Huff, Battelle Memorial Institute**
Stephanie Weber, Battelle Memorial Institute
Dr. John Braggio, Maryland Department of Health and Mental Hygiene
Thomas Talbot, New York State Department of Health
Eric Hall and Fred Dimmick, U.S. EPA ORD/NERL/HEASD

# Project Overview

- ROSES 2010 Earth Science Applications Feasibility Studies: Public Health
- 2-year period of performance: Aug 18, 2011 to Aug 17, 2013
- **Approach**: Combine $PM_{2.5}$ information from ground-based monitors, NASA satellite aerosol optical depth (AOD), and CMAQ air quality model using statistical hierarchical Bayesian model (HBM) to make a single dataset for use in health studies
- **Goal**: Addition of AOD is expected to create more temporally and spatially representative $PM_{2.5}$ concentration fields compared to only monitor data and/or CMAQ
- **Application** to public health end-user programs:
  - National Environmental Public Health Tracking Network
  - Maryland Environmental Public Health Tracking (EPHT) Program
  - U.S.EPA Advanced Monitoring Initiative (AMI) for the Baltimore $PM_{2.5}$ Community of Practice (CoP)

# Preparation of Input Datasets

- Time period of analysis: 2004-2006
- Study regions: Baltimore, MD and New York City, NY
- Prepared **$PM_{2.5}$ input datasets** for each region:
  1. Daily 24-hr average $PM_{2.5}$ concentration measurements from Federal Reference Method (FRM) and Semi-Continuous (SC) **monitors**
  2. Daily 24-hr average $PM_{2.5}$ concentration predictions from **CMAQ** model (12×12 km)
     - Corrected for known seasonal bias of CMAQ relative to monitors
  3. MODIS **AOD** from Terra (10:30 local time) and Aqua (1:30 local time):
     - Converted AOD to $PM_{2.5}$ surface concentrations using season-, satellite-, and location-dependent linear relationships derived for 2004-2006
     - Re-gridded AOD from 10×10 km native resolution to 12×12 km CMAQ grid

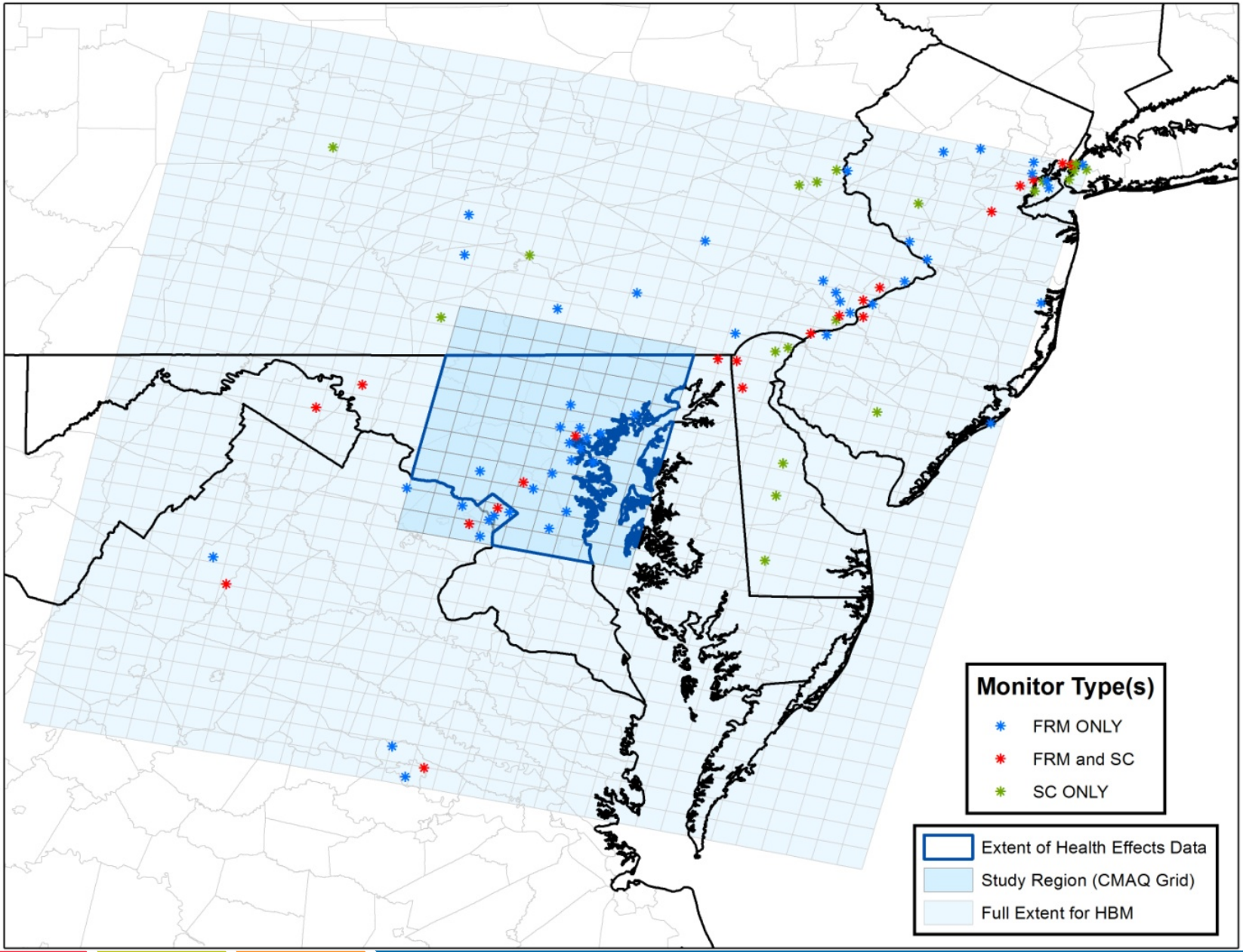
# Generation of Combined Datasets

- Used Battelle/U.S. EPA statistical hierarchical Bayesian model (HBM; "T-SpACE Model") to combine $PM_{2.5}$ input datasets
- HBM was developed for Public Health Air Surveillance Evaluation (PHASE) project to combine $PM_{2.5}$ concentration measurements from **monitors** and predictions of $PM_{2.5}$ concentrations from **CMAQ** in a coherent manner:
  - Best currently available estimate of $PM_{2.5}$ concentration field ("Baseline")
  - Used in National Environmental Public Health Tracking Network
- We revised HBM code to allow for >2 input datasets (to accommodate addition of AOD)
- HBM assumes each input dataset provides information about the underlying true $PM_{2.5}$ concentration field:
  - Monitor data have some measurement error but no bias ("gold standard")
  - CMAQ and AOD have error and bias

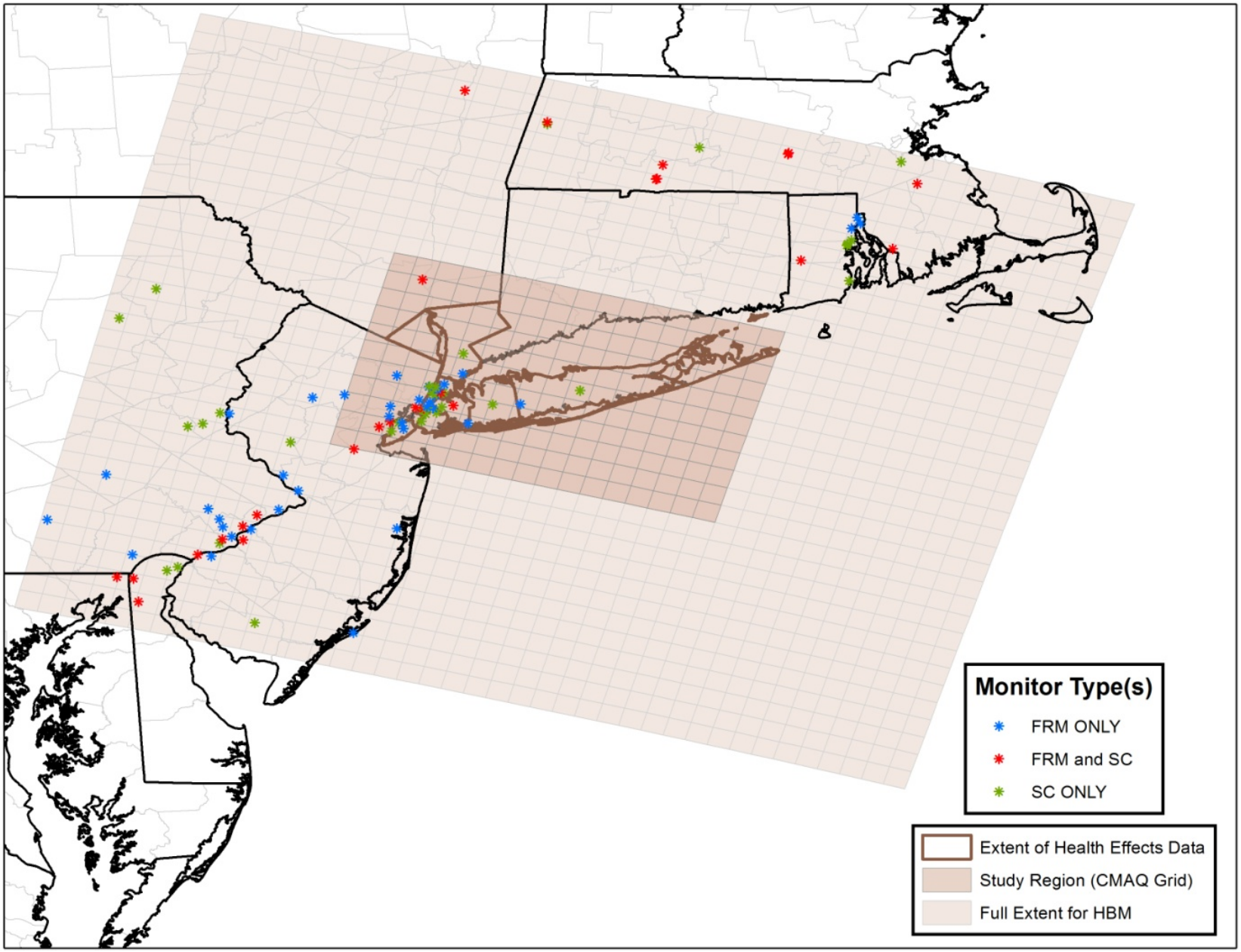
# $PM_{2.5}$ Input and Combined Datasets

| Dataset Identifier | $PM_{2.5}$ Analysis Dataset | Input Dataset 1 | Input Dataset 2 | Input Dataset 3 | Input Dataset 4 |
|---|---|---|---|---|---|
| **B** | **BASELINE** | Monitors | CMAQ | | |
| **1** | **AOD** | Monitors | AOD (missing data) *Aqua* | AOD (missing data) *Terra* | |
| **2** | **AOD_CMAQ** | Monitors | AOD (missing data) *Aqua* | AOD (missing data) *Terra* | CMAQ |
| **3** | **AOD_KRIGE** | Monitors | AOD (kriged) *Aqua* | AOD (kriged) *Terra* | |
| **4** | **AOD_CMAQ_KRIGE** | Monitors | AOD (kriged) *Aqua* | AOD (kriged) *Terra* | CMAQ |
| **5** | **COMBAOD** | Monitors | AOD (missing data) *Aqua/Terra* | | |
| **6** | **COMBAOD_CMAQ** | Monitors | AOD (missing data) *Aqua/Terra* | CMAQ | |
| **7** | **COMBAOD_KRIGE** | Monitors | AOD (kriged) *Aqua/Terra* | | |
| **8** | **COMBAOD_CMAQ_KRIGE** | Monitors | AOD (kriged) *Aqua/Terra* | CMAQ | |

# Baltimore, MD Study Area

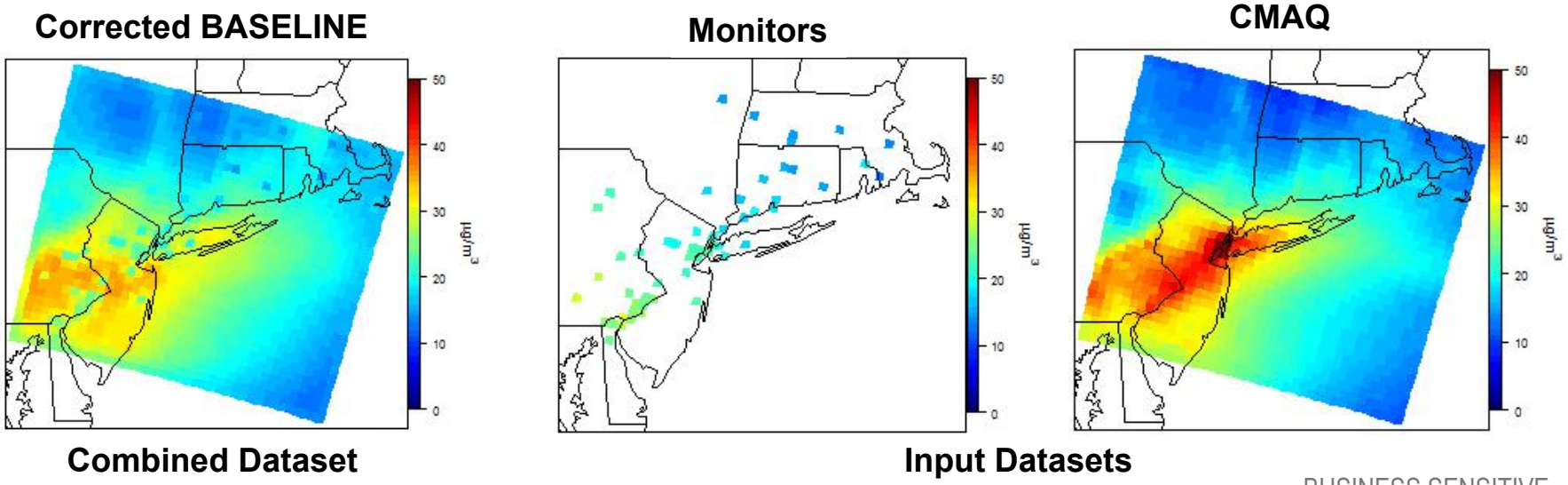


# New York City, NY Study Area



# Issue: Anomaly in Combined Datasets

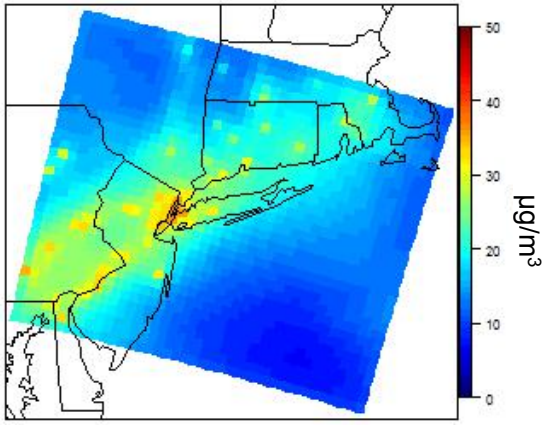
- Review of initial $PM_{2.5}$ combined datasets generated by HBM showed instances of anomalously high $PM_{2.5}$ concentrations ("hotspots")
- Occurred for days when CMAQ input data had much higher $PM_{2.5}$ concentrations compared to monitors (e.g., April 18, 2004 in NYC)
- Caused by allowing bias of CMAQ input data relative to combined output datasets (e.g., BASELINE) to vary in space and time – default option in HBM
- Also observed similar "lowspots" caused by allowing bias of AOD input data relative to combined output datasets to vary in space and time
- Revised HBM to set **constant** bias in space and time for CMAQ and AOD



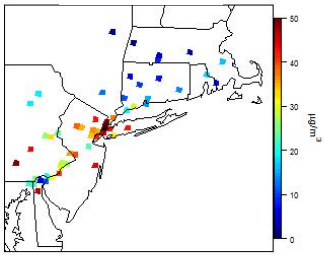
# Sample Results: New York Aug 4, 2005

Battelle
The Business of Innovation

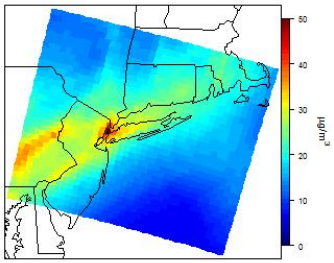
## BASELINE (B)



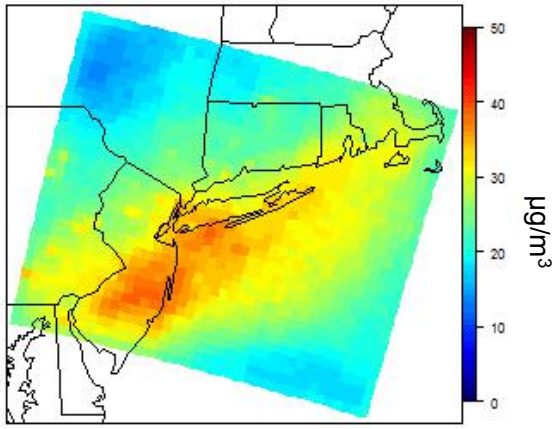

Monitors



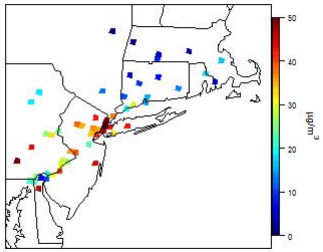
CMAQ



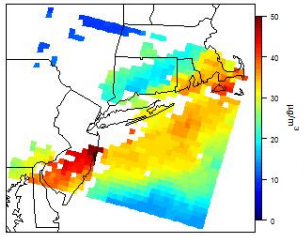
## AOD (1)



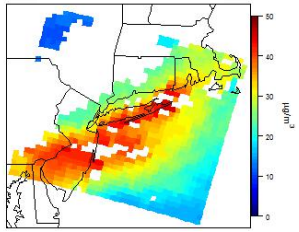

Monitors



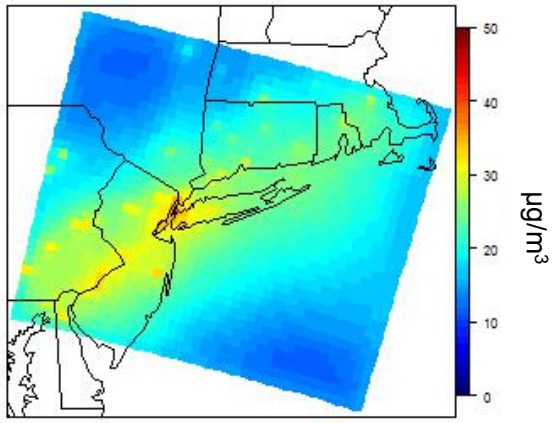
Aqua AOD



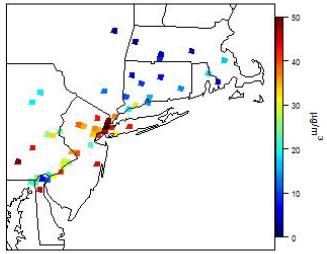
Terra AOD



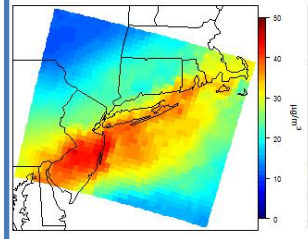
## COMBINED AOD (KRIGE) & CMAQ (8)



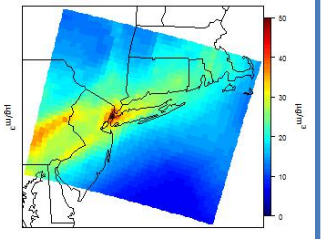

Monitors



Combined AOD (krige)



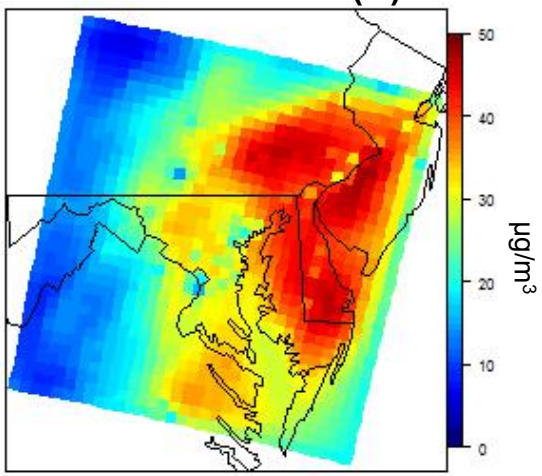
CMAQ



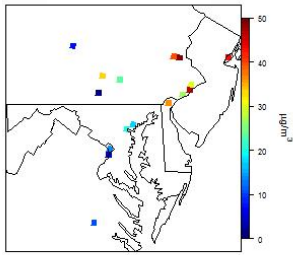
# Sample Results: Baltimore Nov 19, 2004

Battelle
The Business of Innovation

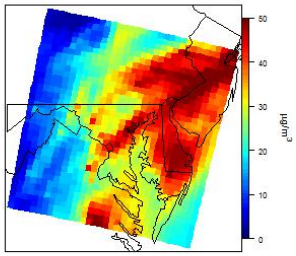
## BASELINE (B)



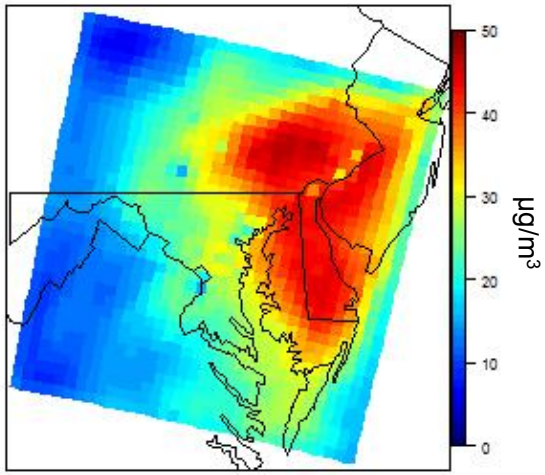

Monitors



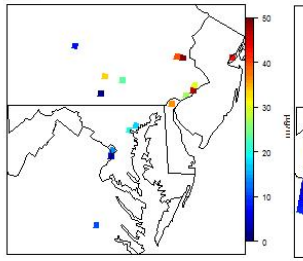
CMAQ



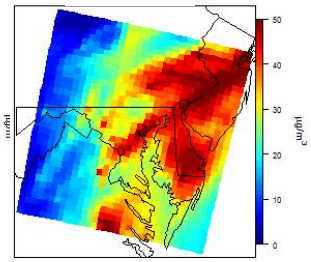
## AOD & CMAQ (2)



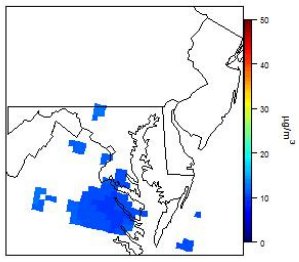

Monitors



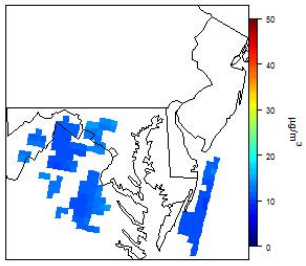
CMAQ



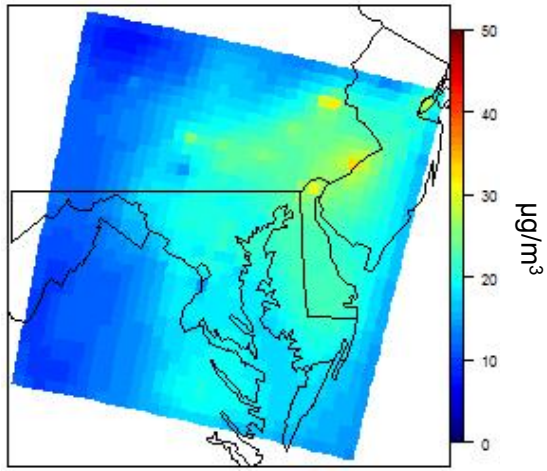
Aqua AOD



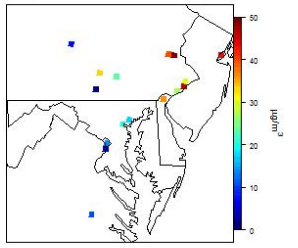
Terra AOD



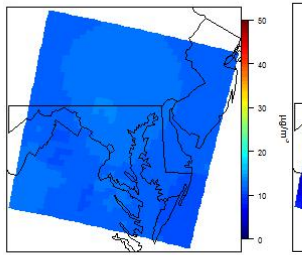
## COMBINED AOD (KRIGE) & CMAQ (8)



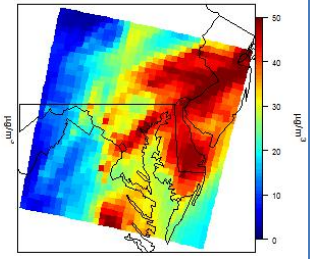

Monitors



Combined AOD (krige)



CMAQ



# Next Steps

- Complete final review of $PM_{2.5}$ combined datasets generated using HBM (mid-late Sept)
- Co-Is at **Maryland Department of Health and Mental Hygiene** (Dr. John Braggio) and **New York State Department of Health** (Thomas Talbot) will conduct statistical analysis on $PM_{2.5}$ combined datasets and health outcome datasets:
  - Asthma visits to ED and hospitalizations
  - Acute MI hospitalizations
  - Ischemic heat disease hospitalizations
  - Heart rhythm and conduction disturbances hospitalizations
  - Cerebrovascular disease hospitalizations
  - Peripheral artery disease hospitalizations
  - Heart failure hospitalizations
- **Goal**: determine if addition of AOD to $PM_{2.5}$ combined datasets increases correlation with health outcomes for Baltimore and New York City regions

# Potential Risk to Project Schedule

- Dr. Braggio has not yet received approval from the Maryland Health Care Commission (MHCC) to use the confidential health data in this project
- Once Dr. Braggio receives approval from MHCC, he will also need to obtain approval of the project's data analysis protocol from the Maryland State Institutional Review Board (IRB)
- Cause of delay in approval is unknown and unprecedented
- Deadline for receiving approval from MHCC without causing delay in analysis for Baltimore region is **late Sept/early Oct**
- Recourse will be to explore options with John Haynes for time extension to allow for completion of Baltimore region analysis
- *All approvals obtained for New York State confidential health data – NY region analysis is set to begin late Sept*

# Project Budget

- Total funding: $149,520
  - Year 1 allocation: $101,519
  - Year 2 allocation: $48,001
- Breakdown by tasks:
  - Generation of $PM_{2.5}$ combined datasets, final analysis: $99,393
  - Baltimore region analysis: $28,202 (graduate research assistant)
  - New York City region analysis: $21,925 (post-doctoral researcher)
- Project-to-date (as of Aug 30, 2012):
  - Spent: $71,759
  - Remaining: $77,761
- Project is **on budget and on time** (aside from delay in approval for use of confidential MD state health data)

# Acknowledgements


- NASA Public Health Applications Program
- John Haynes, Sue Estes, and Ali Omar
- Michele Morara, Battelle Memorial Institute
- Co-Investigators and Collaborators:
  - Stephanie Weber, Battelle Memorial Institute
  - Dr. John Braggio, Maryland Dept of Health and Mental Hygiene
  - Dr. Thomas Talbot, New York State Dept of Health
  - Eric Hall, U.S. EPA
  - Fred Dimmick, retired U.S. EPA

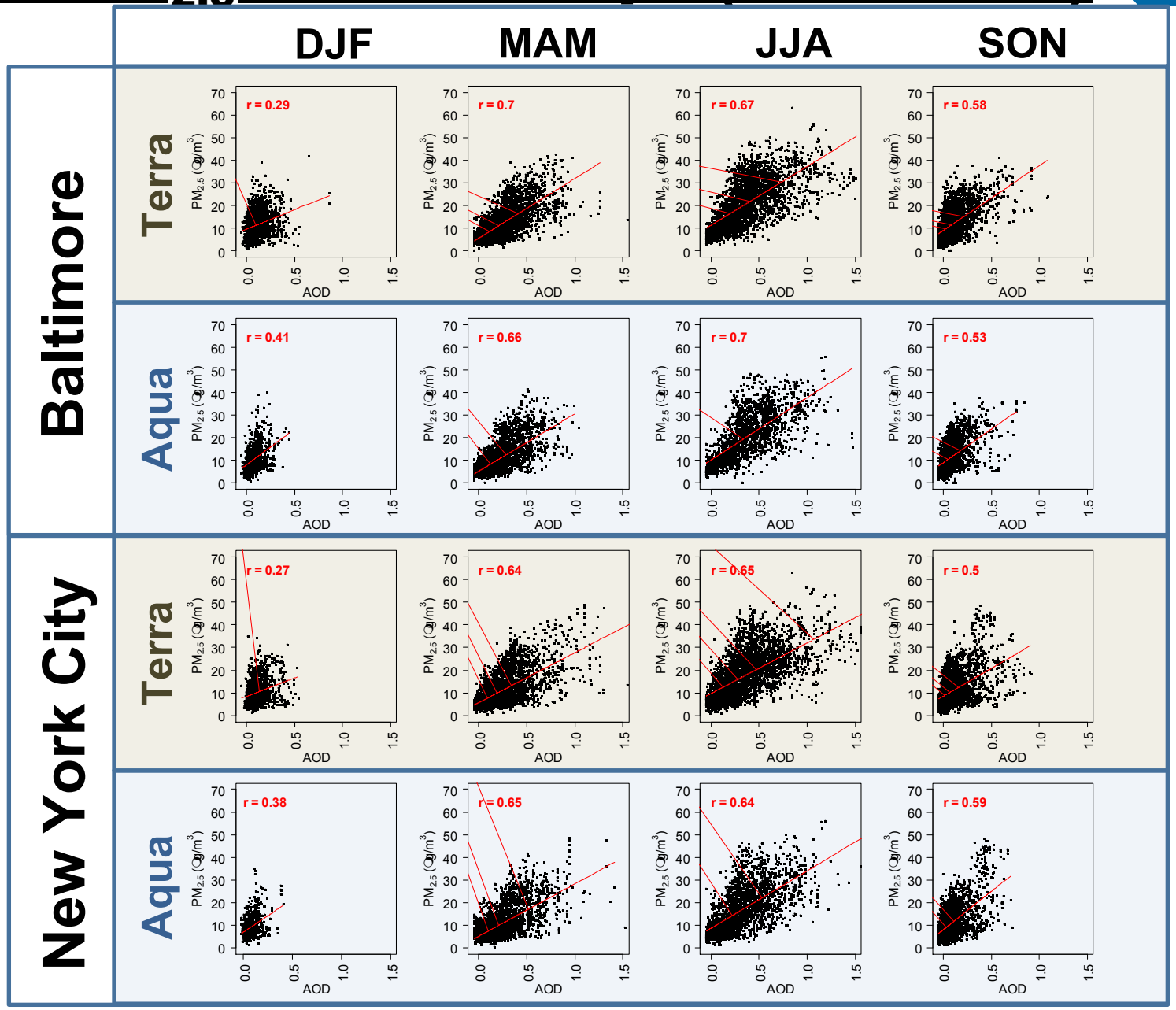




Battelle
*The Business of Innovation*

# AOD-$PM_{2.5}$ Relationships (2004-2006)

Battelle
*The Business of Innovation*



# Variations in AOD and $PM_{2.5}$ Correlation

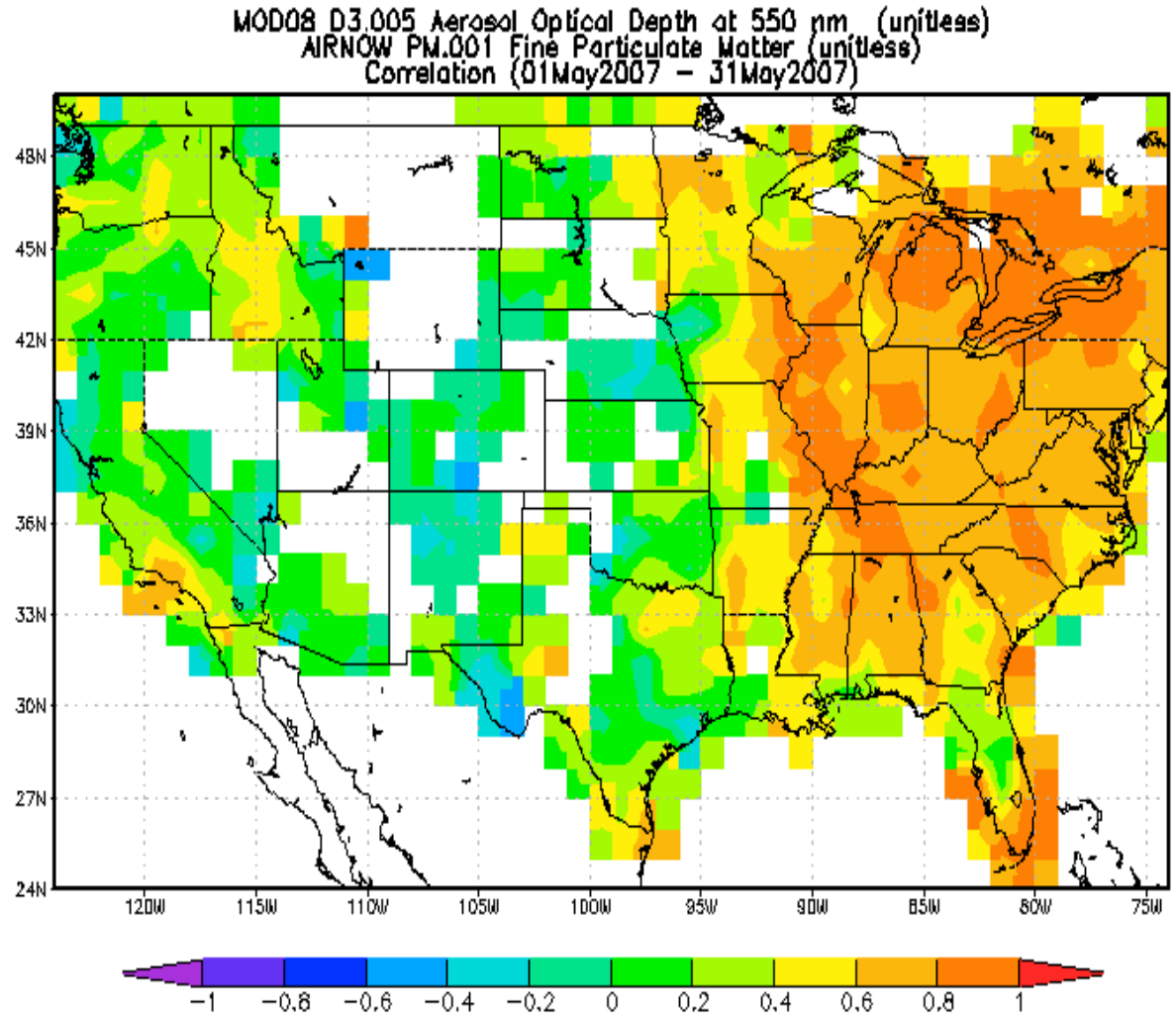
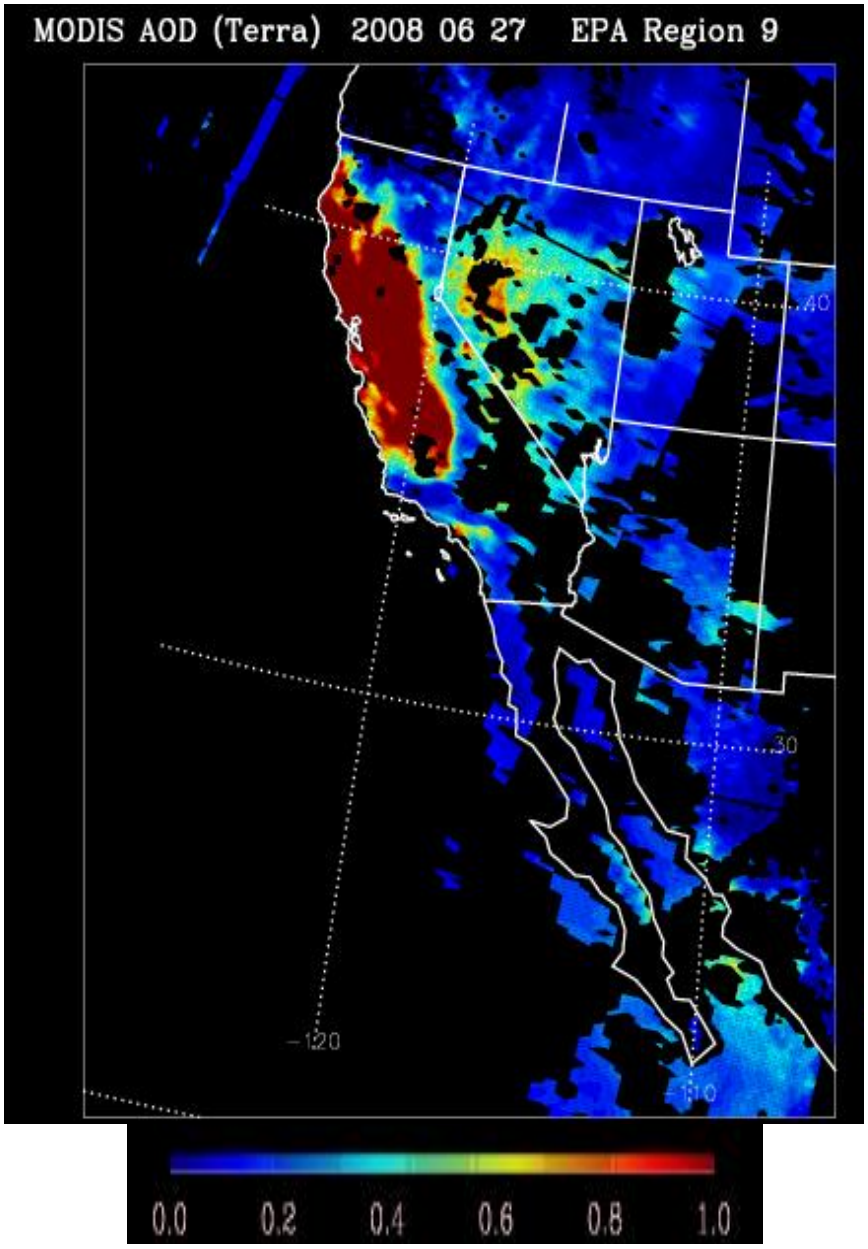



*Image generated by Giovanni , NASA GES DISC*

- Correlations vary by:
  - Region and season
  - Vertical aerosol distribution and properties
  - Meteorological conditions such as relative humidity and boundary layer height
- AOD retrievals are less accurate over bright surfaces such as desert or snow

# Aerosol Optical Depth (AOD)




- AOD is a measure of scattering and absorption of visible light in vertical column between TOA and Earth's surface
- AOD is related to $PM_{2.5}$ concentration; high AOD corresponds to high $PM_{2.5}$
- Values range 0-1 in U.S.
- Project is using AOD measured by MODIS on NASA's Terra and Aqua satellites